

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

FOUR STROKE INTERNAL COMBUSTION ENGINE

Patent number: GB1491231

Publication date: 1977-11-09

Inventor:

Applicant: YAMAHA MOTOR CO LTD

Classification:

- international: F02M25/06

- european: F01N3/26; F02B23/08; F02D13/02; F02M1/04C; F02M3/12; F02M7/17; F02M25/07; F02M25/07B; F02M31/04C; F02M33/04; F02M33/06; F02M69/04C1; F02M69/04C2

Application number: GB19740044378 19741014

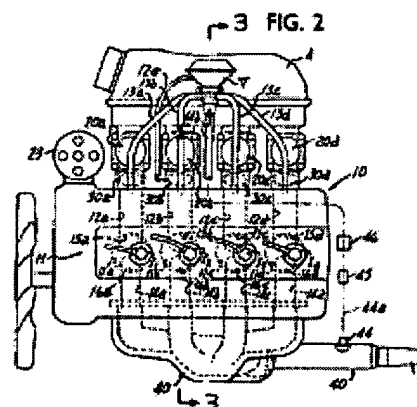
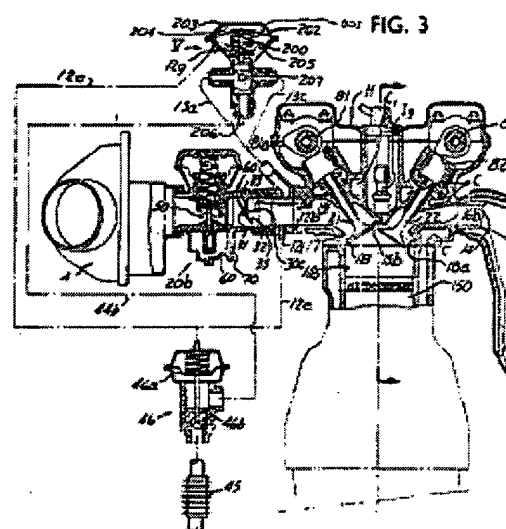
Priority number(s): JP19740073546 19740626; US19740496142 19740812

Also publis

GB1

Abstract of GB1491231

1491231 Exhaust gas recirculation in IC engines YAMAHA HATSUDOKI KK 14 Oct 1974 [26 June 1974 12 Aug 1974] 44378/74 Heading F1B A multi-cylinder four-stroke I.C. engine has an inlet duct and valve controlled inlet and exhaust ports for each cylinder, means for introducing a fuel/air mixture into the inlet ducts and spark ignition means, the inlet ducts being inter-connected with the exhaust pipe of the engine via a valve which controls the flow of exhaust gases towards the inlet ducts, means being provided for restricting the flow of gases by way of the inter-connecting pipe between the inlet ducts in response to short pressure peaks in the inlet ducts. In an engine in which a separate carburettor is provided to feed each cylinder, exhaust gas is drawn from a thermo-reactor 40 and recirculated to the inlet pipe through a cooler 45 and through two vacuum-controlled valves 46 and V 1 in series. The diaphragm 46a of valve 46 is subject to the vacuum immediately downstream of the throttle valve in one of the intake ducts 12b, so that valve member 46b is moved toward the open position when sufficient depression exists in the intake duct. Diaphragm 202 of valve V is pulled downwards by the depression in duct 12b against compression spring 201 to move valve member 200 to reduce or prevent flow of exhaust gas through each of the ports 207 to individual cylinders. Since recirculation pipes 13...d are inter-connected by valve ports 207, the low-pressure in a combustion chamber of which the piston is on the intake stroke may adversely affect the pressure at the intake port of another combustion chamber. To prevent this isolation means are provided in each of the recirculation pipes e.g. reed valves which open to allow flow of exhaust gas and close when a depression exists in valve V. Alternatively the isolation means comprises restrictions in the bore of the pipes 13a...d, which restrict gas flow in response to short pressure peaks, but permit long-term pressure changes. The Specification also discloses that the intake pipes, adjacent the intake ports, are excluded from the effect of the liquid coolant circuit C of the engine and are cooled only by air, so that their temperature is 90 C to 135 C, preferably 110 C so that if a film of fuel forms on the pipe wall it is vaporized. The crank-case interior and/or the fuel tank may be vented by providing a connection to the exhaust gas recirculation pipe.



PATENT SPECIFICATION

(11) 1 491 231

1 491 231

- (21) Application No. 44378/74
- (22) Filed 14 Oct. 1974
- (31) Convention Application No. 49/073546
- (32) Filed 26 June 1974
- (31) Convention Application No. 496142
- (32) Filed 12 Aug. 1974 in
- (33) Japan (JA)
- (33) United States of America (US)
- (44) Complete Specification published 9 Nov. 1977
- (51) INT CL² F02M 25/06
- (52) Index at acceptance

F1B 2F2N 2L3A2 2L3B1 2L3BX



(54) FOUR STROKE INTERNAL COMBUSTION ENGINE

(71) We, YAMAHA HATSUDOKI KABUSHIKI KAISHA, a Japanese Body Corporate, of 2500 Shingai, Iwata-shi, Shizuoka-ken, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a four stroke internal combustion engine having for each cylinder an inlet duct with an inlet port and an inlet valve and an exhaust duct with an exhaust port and an exhaust valve and a mechanism for introducing a mixture of fuel and air into the inlet ducts and ignition means for generating a spark at the spark plugs in the cylinders.

An internal combustion engine is provided with means to operate the same to produce minimal quantities and concentrations of oxides of nitrogen (NO_x), carbon monoxide (CO) and unburned hydrocarbons (HC). The engine is operated with a lead air/fuel mixture at both low and high load conditions, thereby minimizing said emissions. Low load operation on lean mixtures is made possible by means and methods for maintaining at a suitable low numerical value the residual fraction which is defined as the ratio of gases in a cylinder from a previous cycle and the total gases in the cylinder for the next cycle (said gases from a previous cycle plus new mixture). Said means may comprise apparatus to shorten the duration of intake and exhaust valve overlap, or of opening the engine throttle wider than normal and retarding the ignition to reduce the engine speed at low loads. Means is preferably provided wherein the fuel in the air/fuel mixture is well-vaporized and the mixture is uniform and homogeneous. Some of such means may comprise vaporizing means whereby fuel film adherent to the wall of the engine's induction means is vaporized

by heat, or is collected and discharged into the air stream.

The emission of pollutants as a consequence of the operation of internal combustion engines has become a matter of serious concern. Increasingly stringent restrictions being imposed upon these emissions, and the need is pressing for engines which can meet the new standards. The best solution will be one which can use substantial amounts of existing technology and tooling, and can be adapted to engines of current design without requiring radical redesigns and extreme changes in engine concepts and constructions are likely to be less effective because of resistance to change by purchasers and by persons who must learn to make and to service the new mechanisms. Accordingly, delays and inefficiencies can be anticipated when major departures from existing technologies are required.

It is an object of this invention to provide a solution for the problem of emission of pollutants, which can utilize a considerable amount of existing technology, and which requires only relatively small changes and redesigns when incorporated in many or even most conventional internal combustion engines. Other conventional engines may require more extensive modifications which, however, are clearly understandable and simple to put into usage. Therefore, they may be expected to give rise only to minimal resistance to their usage. Accordingly, this invention offers a readily acceptable solution to the problem of pollutant emissions, and one which can be adopted with minimal adversity.

It is an object of this invention to provide internal combustion engines, and methods of operating the same, whereby to minimize the emission of pollutants, especially oxides of nitrogen (generically referred to as "NO_x").

According to the invention, a four-stroke multi-cylinder internal combustion engine has for each cylinder an inlet duct with an inlet port and an inlet valve and an exhaust duct with an exhaust port and an exhaust valve and a mechanism for introducing a mixture of fuel and air into the inlet duct and has ignition means for generating a spark at spark plugs in the cylinders, the inlet ducts being interconnected with the exhaust pipe of the engine via a valve, which controls the flow of exhaust gases towards the inlet ducts, a pipe interconnecting the inlet ducts, means

being provided for restricting the flow of gases by way of the interconnecting pipe between the inlet ducts in response to short pressure peaks in the inlet ducts. It has been shown, that recirculating of a part of the exhaust gases to the combustion chamber has an advantageous effect on the emission of NO_x.

However, the tendency of an engine to misfire is directly related to the numerical value of a mathematical expression hereinafter called the "residual fraction". The "residual fraction" is defined as follows:

$$\text{residual fraction} = \frac{\text{Amount of residual gases remaining in combustion chamber from previous cycle}}{\text{Amount of air (or air/fuel mixture) taken into combustion chamber for next cycle} + \text{Amount of residual gases remaining in combustion chamber from previous cycle}}$$

The term "amount" refers to weight, or to volume measured at like temperature and pressure. As the numerical value of the residual fraction increases, so also does the tendency of the engine to misfire.

In order to prevent, that in low load conditions the residual fraction becomes too high the valve is controlled by the pressure in an inlet duct such, that when the pressure in the inlet duct decreases, the flow of exhaust gases through the valve is decreased also.

In this way it can be prevented, that especially during low load operation the low pressure in one inlet duct has a disadvantageous effect on the flow of mixture towards a cylinder during the intake stroke of said cylinder.

A simple construction will be obtained, when said means are formed by small orifices in said pipe. According to a further possibility said means are formed by unidirectional check valves.

In order to prevent, that the temperature rises too much during the combustion there has been provided a cooler for the exhaust gases between the exhaust pipe and the valve.

A favourable control of the flow of exhaust gases is obtained when a further valve controlled by the pressure in the inlet duct is provided between the exhaust pipe and said valve for controlling the flow of exhaust gases towards the inlet ducts, said last-mentioned valve being arranged to reduce the flow of exhaust gases in response to an increase in vacuum in an inlet duct, and said further valve being arranged to open in response to reduction in vacuum.

A compact construction of the engine can be obtained when said pipe interconnecting the inlet ducts comprises a recirculation duct provided in an inlet manifold and between

the inlet manifold and the cylinder heads there is mounted a plate supporting reed valves respectively connected to the inlet ducts for allowing a flow of exhaust gas towards any of the inlet ducts when the pressure in an inlet duct falls sufficiently to allow the associated reed valve to open.

Such an arrangement can be obtained in a simple way when the inlet ducts are provided with passages covered on one side with portions of the plate having openings connecting the inlet ducts with said recirculation duct, said reed valves controlling the flow through the openings.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, in which:—

Figure 1 is a generalized graph showing the output of certain pollutants versus the air/fuel ratio on which an engine is operated;

Figure 2 is a top view of one embodiment of the invention with some parts removed for clarity of disclosure;

Figure 3 is a partial cross-section taken at line 3—3 of Figure 2;

Figures 4, 5, 6 and 7 are fragmentary cross-sections, partly diagrammatic, showing portions of the system of Figure 2; and

Figure 8 is an arrangement of a balance pipe in the inlet manifold.

Fig. 1 is a generalized, undimensioned showing of the emission of pollutants emitted plotted as the ordinate, versus the air/fuel ratio of the mixture which is burned in the engine plotted as the abscissa. This graph is generally true of all internal combustion engines. In addition to the pollutants CO, HC and NO_x, the unobjectionable gases carbon dioxide (CO₂) and oxygen (O₂) present in the exhaust gases are shown.

Fig. 1 shows that when mixtures leaner than stoichiometric (about 15 for gasoline)

15

20

25

75

80

85

90

95

100

105

110

are burned in an engine, HC and CO emissions decrease dramatically compared to those which are emitted as the consequence of burning a richer mixture. This observation is also true of the emission of oxides of nitrogen when mixtures with a ratio greater than about 16 are burned. It is therefore a considerable advantage to operate the engine with air/fuel mixtures whose air/fuel ratios are leaner than stoichiometric, and which preferably are in the range between about 16 to 20, in order to minimize the emission of these pollutants.

Figs. 2 and 3 illustrate one embodiment of the invention. A four-cycle internal combustion engine 10 includes four combustion chambers 11a, 11b, 11c and 11d. The term "cylinder" is sometimes used synonymously with the term "combustion chamber". This engine is provided with one throttle valve 30a, 30b, 30c and 30d and with one carburetor 20a, 20b, 20c and 20d for each of the combustion chambers. Individual intake pipes 12a, 12b, 12c and 12d communicate respectively with the intake ports 15a, 15b, 15c and 15d of respective combustion chambers 11a, 11b, 11c and 11d. The intake pipes constitute one embodiment of "induction means" used in the invention to supply a charge to the combustion chamber.

Exhaust pipes 14a, 14b, 14c and 14d respectively communicate with and receive exhaust gases from exhaust ports 16a, 16b, 16c and 16d from combustion chambers 11a, 11b, 11c and 11d. The exhaust pipes and an exhaust system P which collects gases from the pipes comprise one embodiment of "exhaust means" used in the invention to remove spent charge from the combustion chambers.

Exhaust gas recirculation pipes 13a, 13b, 13c, 13d are respectively connected to intake pipes 12a, 12b, 12c and 12d. Pipes 13a-d in turn are connected to an exhaust gas recirculation valve V. Vacuum line 12e (Figs. 2 and 3) interconnects port 12f in intake pipe 12b and port 12g in control valve V. Intake pipes 12a, 12c and 12d are not connected to port 12g. Exhaust gas recirculation pipes are used when NO_x is to be controlled by the recirculation of part of the exhaust gases into the incoming air/fuel mixture.

Attention is now directed to Fig. 3 where there are shown in more complete detail certain features of Fig. 2, especially those parts which are directly related to combustion chamber 11b. The other cylinders and their provisions are identical, and this is exemplary of all of them. Therefore, the others will not be individually described.

An intake valve seat 18 surrounds intake valve port 15b. Exhaust valve seat 18a surrounds exhaust valve port 16b. Intake valve 21 and exhaust valve 22 are slidably mounted in the cylinder head and are adapted to move

against the respective valve seat to close the port, or to move away from the seat to open it. Cams 81a and 82a, fixed respectively to cam shafts 81 and 82, are provided to open the valve ports, and the valves are spring-loaded to close when the cams do not hold them open. Similar sets of intake and exhaust valves and seats, and cam means and return springs, are provided for each of the combustion chambers.

Cylinder head H of combustion chamber 11b is shown, together with a cooling water jacket C. Cooling jacket C shrouds only the exhaust pipe adjacent to the outlet port and the combustion chamber itself. A region 17 which extends from inlet valve seat 18 upstream into the inlet pipes is not cooled by the cooling jacket C. Instead, it is permitted to become heated by heat from the combustion chamber for purposes yet to be described. This region may even be externally insulated or heat-jacketed to increase or maintain elevated temperature.

Region 17 preferably extends at least for a distance of about 60 to 70 mm upstream from the intake valve seat toward the intake pipe, and is regarded as part of the intake pipe, even though all or a portion of it may be formed integrally with the cylinder head. Region 17 is bounded by the inside wall 19 of the intake pipe, and the wall is thermally continuous with the cylinder head, i.e., the inside wall of the intake pipe is heated by heat conducted to it from the combustion chamber dome. This enables the internal wall 19 of region 17 to warm up, and it is not appreciably cooled by cooling means such as jacket C. Any cooling means is sufficiently spaced from the region 17 that the wall 19 can operate at the necessary temperatures as the consequence of heat conducted to it from the cylinder. A portion C₁ of the jacket is shown in Fig. 3 in the cylinder head above the intake port. In liquid-cooled engines, the cooling passages should extend to this side of the head, but it is not desired for them to cool the said region. Accordingly, there is a sufficient thickness of material between portion C₁ of the cooling jacket and wall 19 that enough heat is conducted to wall 19 to warm it sufficiently, despite the presence of portion C₁. Region 17 is one embodiment of "vaporizing means" for vaporizing liquid fuel which may have collected on the wall of the inlet pipe.

An ignition distributor 23 is schematically shown in Fig. 2. Conventional condensers, breaker points, cam, and cam shaft, are utilized to provide a spark to ignite the mixture in the combustion chamber.

Exhaust gas recirculation valve V includes a plunger 200 which is biased by a spring 201, and is attached to a diaphragm 202 that is mounted to the wall of a body 203.

Body 203 forms a vented chamber 204 and a vacuum chamber 205.

This bias spring tends to move the plunger to the elevated position as shown in solid line in Fig. 3. Exertion of vacuum in the vacuum chamber 205 will move the plunger downwardly. When the plunger moves downwardly by a sufficient distance (Fig. 7), it will reduce or close off entirely the flow of gases from inlet 206, from which the flow would otherwise be distributed through four outlet ports 207 to recirculate pipes 13a—d. It follows that the amount of recirculation of gases yet to be described will be a function of the degree of vacuum in inlet pipe 12b.

The principal advantage of providing one throttle valve per combustion chamber is that the pressure in one intake pipe is not reduced by the pressure in another intake pipe. In engines where one intake manifold and throttle valve supply a plurality of combustion chambers, the lower pressure in a combustion chamber of which the piston is on its intake stroke may adversely affect the pressure at the intake port of a different combustion chamber. The usage of one throttle valve per combustion chamber allows each combustion chamber to set its own intake conditions. However, recirculation pipes 13a—d do interconnect all of the inlet pipes, and as such could tend to equalize their pressures, thereby reducing some of the values otherwise attainable by the usage of one throttle valve per combustion chamber.

To avoid this adverse result, isolation means is provided in the respective recirculation pipes. In Fig. 4 this isolation means comprises unidirectional check valves 208. As examples, reed valves are shown, which constitute flexible blades 208a mounted to a chamber wall by a fastener 208b, each of which blades tends to close its respective recirculation pipe except in response to differential pressure sufficient to deflect it. One of the valves in intake pipe 12c is shown deflected by a sufficient differential pressure. All can be open at once when there is a sufficient pressure from valve V. However, when a sufficiently large negative pressure exists in the line from valve V, perhaps from one of the intake pipes at a high vacuum (12c in Fig. 4), the other valves will close as illustrated. Moreover, it will be clear that the reed valves constitute means for restricting the flow of gases between the recirculating pipes in response to short pressure peaks in these inlet pipes or ducts 13a—d.

In some cases in engines having one throttle valve and carburetor for each cylinder it is advantageous to have a connection between the inlet ducts during high load conditions. Then it is useful to use the arrangement shown in Fig. 5 wherein the isolation means comprises orifices 209 of sufficiently small bore as to restrict the flow of gases in re-

sponse to short pressure peaks, but which are large enough to permit a more gradual adjustment to pressure changes in the inlet ducts. By using such an arrangement of isolation means during idling whereby when the pressure in an inlet duct is low the pressure in one inlet duct is substantially not affected by the pressure in another inlet duct, whilst during high load condition the pipe interconnecting the inlet ducts has an equalizing effect on the pressure differences in the inlet ducts and can be used also for recirculating the exhaust gases.

A piston 150 is reciprocally fitted in each combustion chamber. The piston turns the crankshaft through a conventional wrist-pin, rod and crank arrangement (not shown).

Each carburetor 20a—d, inclusive, includes a high load circuit 50, a low load circuit 60, and a starting circuit 70. Circuits 50 and 60 supply air/fuel emulsions which, when mixed with air passed by the throttle, will provide a lean mixture to the combustion chamber of the correct ratio. Starting circuit 70 also supplies a lean air/fuel mixture, but the mixture ratio it supplies may have a lesser numerical value than the mixtures supplied by circuits 50 and 60, so that when the engine begins its warm-up after being started by cranking, the combined mixture from the starting circuit and from the low load circuit might average about stoichiometric.

Throttle valve means 30a—d (of which throttle valve means 30c is exemplary) includes a throttle shaft 31 rotatably supported in the wall of the intake pipe or manifold. It includes a disc 32 secured to the shaft 31, which disc acts as a butterfly valve when the shaft is turned. A throttle arm is pinned to the shaft and connected to the accelerator (not shown). Rotating the arm as a lever will rotate the shaft and adjust the position of the valve disc in the pipe so as to vary the area of the pipe which is open to flow of fluid therethrough.

The region 17 of the intake pipe adjacent to the intake valve seat constitutes a "vaporizing means". The wall 19 of this region is operated at an elevated temperature. The wall of this region should be maintained at a temperature between about 90°C and 135°C. In liquid-cooled engines, a temperature of 110°C appears to give optimum results. A film of gasoline will be vaporized at these temperatures. The temperature should not be so high that the entire charge will be heated, because this would be a disadvantage. Wall temperatures between about 90°C and 135°C appear to avert this adverse result.

The term "vaporizing" is used to denote the transfer of the liquid into the stream of air/fuel mixture. The term does not necessarily mean that the fuel has been converted to a gas. Indeed, much of the fuel

70

75

80

85

90

95

100

105

110

115

120

125

130

in the mixture is in the form of small sized droplets of liquid, perhaps surrounded by gas, and the stream will of course include some gas from the lower boiling point constituents of the fuel. The term "vaporizing" is used in the broad sense of the removal of a liquid from a surface, and its reintroduction into the stream of mixture.

When an aluminium cylinder having a bore of about 70 to 90 mm is used, an axial length of uncooled region 17 about 60—70 mm long is useful. A thickness of cylinder head contiguous to the inlet pipe or manifold of about 13 to 15 mm is useful. The wall thickness of region 17 should not be less than about 6 mm. Attention is called to the fact that the usual head thickness of a conventional cylinder is on the order of only about 9 mm, and the wall thickness of the intake pipe only about 4 mm. The greater thickness, especially of the combustion chamber dome in this invention provides for ready conduction of heat to region 17 and isolates the region from any cooling jacket which may be used.

The arrangement for the warmed wall shown in Fig. 3 will operate at temperatures in the desired range without insulation or jacketing. However, insulation could be provided at this region. Also, the region could be jacketed and warmed with hot exhaust gases, if desired or necessary.

HC emissions can be reduced by the use of a thermal reactor 40 which receives the exhaust gases from the exhaust ports and holds them long enough at an elevated temperature for the HC to be oxidized by oxygen which remains in the exhaust gases. Such a reactor when used forms part of the exhaust means. A suitable thermal reactor is best shown in Figs. 2 and 3. It comprises an outer casing 41 around an enlarged portion of each of the exhaust pipes 14 and an inner casing 42 between them. A space 43 is formed between the casings. This space 43 may be filled with solid insulating material, or may simply be filled with air to serve as insulation. Space 43 and whatever is in it serves as insulating means to keep the reactor hot by retaining its heat.

For the purpose of suppressing NO_x formation, exhaust gases are withdrawn from the reactor through a port 44 (Fig. 3) and passed through a cooler 45, thence to an exhaust gas control valve 46, and finally through conduit 44b to exhaust gas recirculation valve V. A conventional exhaust gas control valve 46 includes a diaphragm-actuated plunger 46b, whose movement is the consequence of vacuum applied above a diaphragm 46a and received from pipe 12e. When the manifold pressure is appropriate, valve 46 is opened to recirculate some of the exhaust gases through pipe 44b to the

inlet of valve V, and thence to the inlet pipe.

When the engine of Figs. 2 and 3 is operated at high load conditions, wherein the throttle valve is substantially open and the intake pipes (sometimes called an "intake manifold") operate at relative low vacuum (relatively high intake pressure), there is little difficulty in operating the engine with a lean mixture.

At starting, exhaust gas recirculation valve V remains closed. This prevents or limits exhaust gas recirculation during starting. It is best practice not to recirculate exhaust gases at this time, because to do so would increase the residual fraction by recirculating some exhaust gas, and at cold unstable conditions this could adversely affect the operation of the engine.

Exhaust gas control valve 46 is opened in response to reduction of vacuum within the intake pipe (increase in pressure), and the amount by which the vacuum control valve is opened is varied in accordance with the degree of this vacuum. Exhaust gases are conveyed through the exhaust port 44, conduit 44a, exhaust gas control valve 46, and pipe 44b (see Fig. 6). When insufficient vacuum is present, valve 46 is closed (Fig. 7).

It will be seen that the amount of the residual gases in the embodiment of Figs. 2 and 3 is determined in part by the amount of opening of the exhaust gas recirculation valve V (which affects the fraction by supplying residual gases to the intake pipes). The limiting of recirculation exhaust gases, is to maintain at a suitable value the said residual fraction when operating under low load conditions. Valve V may either be a simple off-on valve, or may be a metering type valve with off-on positions as well.

The present invention is useful in four-stroke internal combustion engines generally. It may be used in engines having any number of cylinders, such as straight 6's and V-8's, as well as in four-cylinder engines. It also can be used with the so-called stratified intake system with auxiliary combustion chamber.

Fig. 8 shows an arrangement whereby the intake pipe 12 of each cylinder comprises an upwardly extending passage 12b. On the free ends of the intake pipes has been mounted a plate 250 arranged between the cylinder head and an intake manifold 251. In said manifold have been provided passages 252 which are in communication with the intake passages 12 for admitting the mixture to the engine via openings provided in the plate 250. Further openings 253 in the plate 250 cooperate with reed valves 254 corresponding with the reed valves 208 of Fig. 4.

In the manifold 252 there has been provided a duct 255 forming a recirculation

duct for the exhaust gases. The duct 255 is in communication with apertures 256 in the manifold via bores 257. The apertures 257 are situated opposite the openings 253.

5 In this way a compact arrangement of the recirculation system of the outlet gases can be obtained.

10 It is also very advantageous to connect the interior of the crank case and/or the interior of the fuel tank with an exhaust gas recirculation pipe. Then gases flowing past the pistons towards the crank case and/or fuel evaporated in the tank will be carried into the engine and burnt.

15 The four-stroke internal combustion engine described above is also described in patent application 44377/74 which relates to a method of operating an internal combustion engine wherein the mechanism for introducing the mixture of fuel and air and the ignition means are adjusted so that in the idling state and low load conditions of the engine a mixture with an air/fuel ratio higher than 15 is introduced in the inlet duct and the ignition occurs after top dead center in the idling state.

WHAT WE CLAIM IS:—

30 1. A multi-cylinder four-stroke internal combustion engine having for each cylinder an inlet duct with an inlet port and an inlet valve and an exhaust duct with an exhaust port and an exhaust valve and a mechanism for generating a spark at spark plugs in the inlet duct and having ignition means for generating a spark at spark plugs in the cylinders, the inlet ducts being interconnected with the exhaust pipe of the engine via a valve, which controls the flow of exhaust gases towards the inlet ducts, a pipe interconnecting the inlet ducts means being provided for restricting the flow of gases by way of the interconnecting pipe between the inlet ducts in response to short pressure peaks in the inlet ducts.

45 2. An engine according to Claim 1, in which the valve is controlled by the pressure in an inlet duct such, that when the pressure in the inlet duct decreases, the flow of ex-

haust gases through the valve is decreased also.

3. An engine according to Claim 1 or Claim 2, in which said means are formed by small orifices communicating with said interconnecting pipe.

4. An engine according to Claim 1 or Claim 2, in which said means are formed by unidirectional check valves.

5. An engine as claimed in any of the preceding claims in which a cooler for the exhaust gases is provided between the exhaust pipe and the valve.

6. An engine according to Claim 2, in which a further valve controlled by the pressure in the inlet duct is provided between the exhaust pipe and said valve for controlling the flow of exhaust gases towards the inlet ducts, said further valve being arranged to open in response to reduction in vacuum.

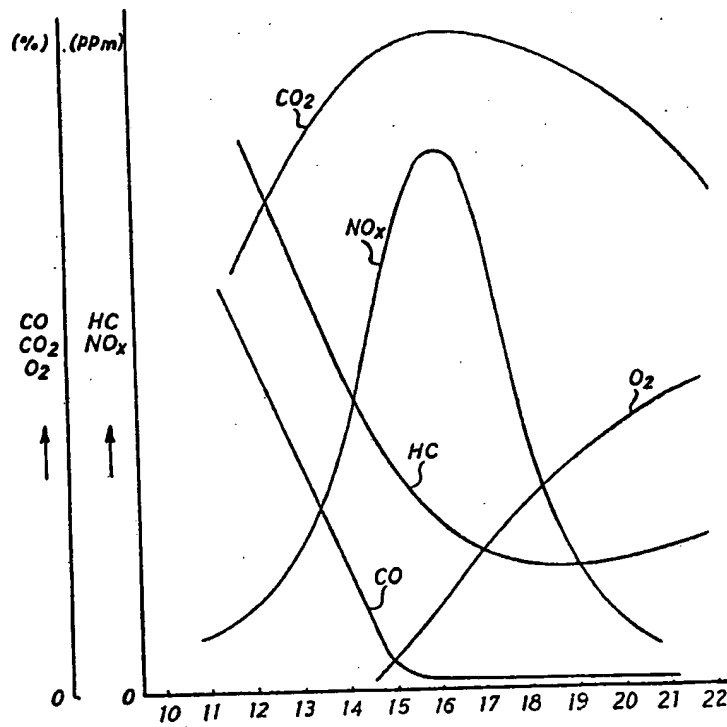
7. An engine according to Claim 1, in which said interconnecting pipe comprises a recirculation duct provided in an inlet manifold and between the inlet manifold and the cylinder heads there is mounted a plate supporting a plurality of reed valves respectively connected to the inlet ducts for allowing a flow of exhaust gas towards any of the inlet ducts when the pressure in an inlet duct falls sufficiently to allow the associated reed valve to open.

8. An engine according to Claim 7, in which the inlet ducts are provided with passages covered on one side with portions of the plate having openings connecting the inlet ducts with said recirculation duct, said reed valves controlling the flow through the openings.

9. A multi-cylinder four-stroke internal combustion engine substantially as hereinbefore described with reference to the accompanying drawings.

Agents for the Applicants:
NPM NEW PRODUCT
MANAGEMENT,
5, Stone Buildings,
Lincoln's Inn,
London, WC2A 3XT.

FIG. 1



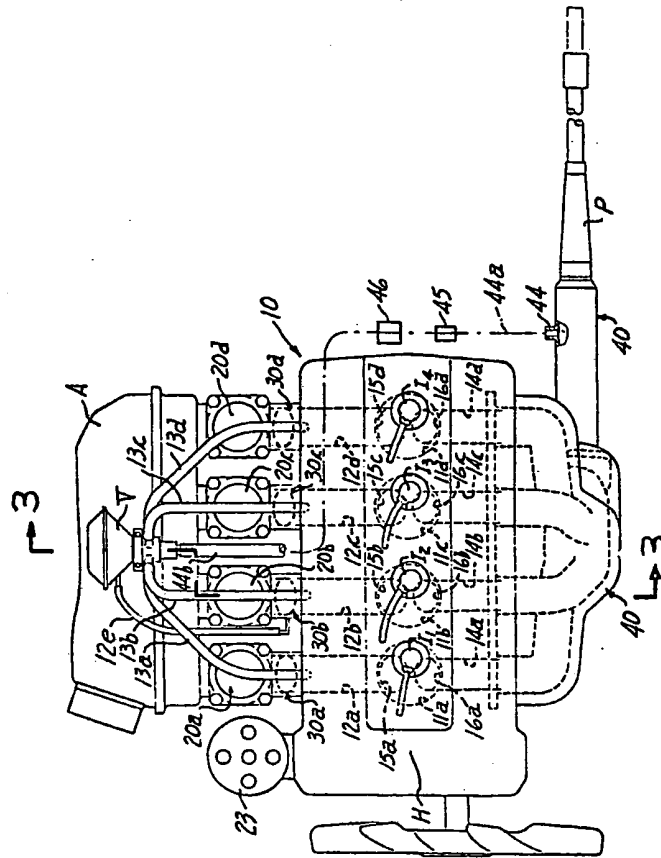
1491231

COMPLETE SPECIFICATION

5 SHEETS

This drawing is a reproduction of
the Original on a reduced scale

Sheet 2



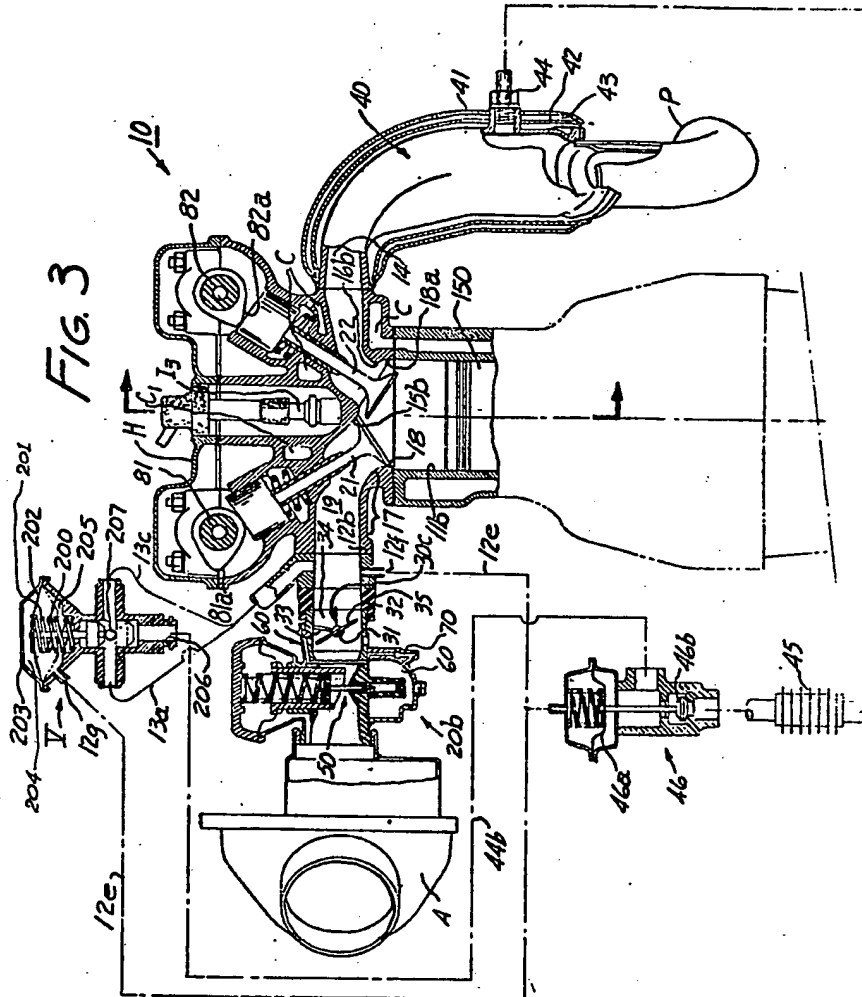


FIG. 4

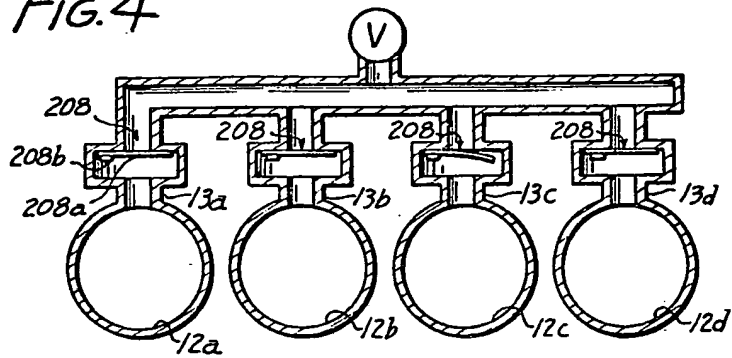


FIG. 5

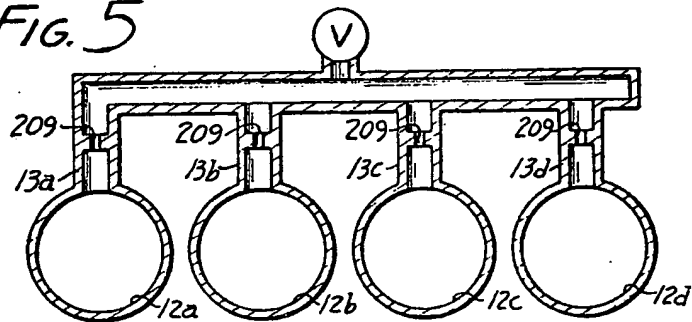


FIG. 6

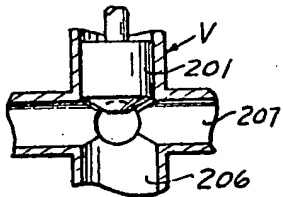


FIG. 7

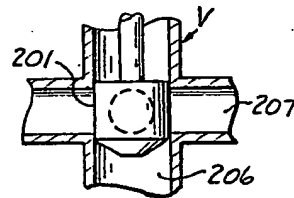


Fig. 8

